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Jose Ramos

UNITED STATES PATENT APPLICATION

FOR

RINGING AND INTER-SYMBOL INTERFERENCE REDUCTION IN OPTICAL COMMUNICATIONS

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BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to the field of optical communications, and in particular to a method and apparatus for inter-symbol interference reduction in optical communications.

2. BACKGROUND ART

Communications systems operate by sending a signal from a sender to a receiver. Generally this signal is an electrical signal but some optical based communications systems use light instead of electricity. Data is sent as a series of light pulses that may be produced by a laser and sent on an optical fiber or even through the air. One way that optical communications systems send a light signal is by directly modulating the current supplied to the laser. The changing current causes the intensity of the laser beam to vary, resulting in light pulses.

A number of problems can occur in high-speed modulation of optical components such as direct modulated laser diodes. In a typical output for a direct modulated laser, there is an overshoot followed by an undershoot for transitions from low to high. Similarly, there is an undershoot for transitions from high to low. This phenomenon is called "ringing," and the ringing effect from a transition decreases over time. As a consequence of the undershoot the high level of the laser is decreased for a certain period of time, which increases the risk for transmission errors at the receiver. Further, if the ringing effect persists over a time frame larger than a single bit slot it may even interfere with the signals of the following slots.

The phenomenon of previous bit slots contributing to the amplitude of a signal is termed "inter-symbol interference." Inter-symbol interference causes negative effects such as increased bit-error rates at the receiver. When the pulse rates are relatively slow (e.g. millions of bits per second, or megabits), the ringing can be tolerated since it only occupies a very small portion of a single bit slot. But when the pulse rate is higher (e.g. billions of bits per second, or gigabits), the ringing prevents the accurate transmission of information and data.

The ringing frequency is dependent of the relaxation frequency of the lasers. However, due to the non-linear characteristics, the relaxation frequency will vary with the pulse amplitude, and cannot be removed by filtering. For example, in a typical output for a direct modulated laser, the oscillation of the ringing at the lower level is much slower than at the upper level.

Another problem with current methods of laser modulation is frequency modulation of the light output, termed "chirp." The chirp generates a pulse shape distortion as the signal is transmitted through a fiber with non-zero group velocity dispersion. The pulse shape distortion increases the power necessary at the receiver for sufficiently error free detection. The need for the increase in power is called dispersion penalty.

Prior art method of generating laser pulses, referred to as "direct modulation" lead to ringing, inter-symbol interference and chirp in optical communications resulting in a loss of performance. This problem can be better understood by a review of direct modulated laser signals.